TECHNICAL PROGRESS REPORT 324
NOTS TP 3276
COPY 5

INVESTIGATION OF EXPLOSIVES SENSITIVITY TO MULTIPLE-FRAGMENT IMPACT

(Track Test E-7380)

by

L. M. Polton
Test Department

ABSTRACT. In a second series of multifragment impact track tests in the ASESB dividing wall program, a rocket-powered sled was used to throw collections of fragments at explosive acceptor charges. Of the 13 rounds in this series, five, having a fragment velocity of 750 fps, produced five acceptor detonations; four rounds, at 470 fps, produced three detonations; and four rounds, at 330 fps, produced no detonations. The presence or absence of detonators in the acceptor charges had little apparent effect upon results. Specific warhead and explosives data relative to this series appear in Confidential Restricted Data report TPR 324, Supplement, NOTS TP 3277.

Results of the first series of multifragment impact track tests are reported in NAVWEPS Report 8073, NOTS TP 3090 (Unclassified), dated December 1962.

U.S. NAVAL ORDNANCE TEST STATION

China Lake, California

July 1963

U. S. NAVAL ORDNANCE TEST STATION

AN ACTIVITY OF THE BUREAU OF NAVAL WEAPONS

C. BLENMAN, JR., CAPT., USN
Commander

WM. B. MCLEAN, PH.D.
Technical Director

FOREWORD

The tests described in this report were conducted in January 1963 as part of the investigation of the mechanisms of propagation in the Armed Services Explosives Safety Board (ASESB) dividing wall program. The dividing wall program is supported by funds from the three military services and from the Defense Atomic Support Agency under Task Assignment RUME-3E-000/216-1/F008-10-04, and local project Nos. 556, 657, 669, and 678.

These tests are a continuation of the investigation which began with an earlier series of track tests described in NAVWEPS Report 8073, NOTS TP 3090. This second series has provided additional data on the effect of fragment velocity upon acceptor sensitivity. In also presenting an opportunity to make a preliminary evaluation of a modified acceptor type, it appears to have broadened the application of other test results in this program.

It is planned to do further testing of explosives sensitivity to multiple-fragment impact at NOTS under the Picatinny Arsenal research phase of the dividing wall program. A different test method, designed for economical testing of a large number of rounds, is currently under development by the Range Engineering Branch of the Test Department.

This report was prepared primarily for the information of the Dividing Wall Work Group. It has been reviewed for technical accuracy by D. P. Ankeney, U. S. Naval Ordnance Test Station, and R. G. Perkins, Armed Services Explosives Safety Board Dividing Wall Work Group.

R. A. APPLETON
Head, Range Division

Released under
the authority of
WM. B. McLEAN
Technical Director

NOTS Technical Publication 3276
Technical Progress Report 324

Published by . . . . Test Department
Manuscript 30/MS-586
Collation. . . . . Cover, 14 leaves, abstract cards
First printing . . . . .75 numbered copies

CONTENTS

ACKNOWLEDGMENT

Acknowledgment is made of the work done by J. S. Ward and F. C. Scheberies in connection with the modification and operation of the fragment-throwing vehicle used in this test series.

INTRODUCTION

The impact of multiple wall fragments as a mechanism of propagation of explosions was isolated for the first time in a series of tests conducted at the U. S. Naval Ordnance Test Station in July 1962 and described in NAVWEPS Report 8073.* The results of those tests conclusively established that multiple-fragment impact can cause initiation of explosive acceptor charges.

A second series of similar tests was planned to obtain data that could be used in establishing the effect of fragment velocity on propagation. Although the original test plan called for 16 rounds to be fired at selected velocities between 300 and 850 fps, circumstances limited the actual number fired to 13. The choice of velocity range was based on data from cubicle tests and the earlier track test series.

The test plan also provided for a comparison of the sensitivity of the standard dividing wall acceptor charge to fragment impact with that of the same basic charge assembled without detonators. If the effect of the detonators proved to be limited, the results of previous dividing wall tests in which the standard acceptors were used could be interpreted to apply to a broader range of actual operating conditions.

The same overall test arrangement described in NAVWEPS Report 8073, using the K-2 terminal ballistics track and the NOTS-developed fragment-carrying sled, was employed for this second test series. Minor modifications to the test equipment and method were made and the instrumentation system was improved to increase the reliability of the velocity data.

---

*U. S. Naval Ordnance Test Station. Investigation of Explosives Sensitivity to Multiple-Fragment Impact Track Tests (E-7101), by L. M. Patton. China Lake, Calif., NOTS, December 1962. (NAVWEPS Report 8073, NOTS TP 3090).

TEST SETUP

TEST VEHICLE AND FRAGMENT CONTAINER

Two 5-inch HVAR rocket motors were used as the main sled structure. The fragment container, with a frangible plastic cover reinforced with tape across the open front end,* was attached (lying on its side) to the top of the motors. Auxiliary structural members were used to support the container. On the front of the sled was a water-brake wedge, shaped to force the water out to either side. Test vehicle and container are shown in Fig. 1.

FRAGMENTS

The fragment specimen for each round weighed an average $71\frac{1}{2}$ lb and contained the following material:**

Concrete--50 lb ($+0, -3\frac{1}{2}$)	Approx 6 pcs, 4 to 8 in. diameter Approx 5 pcs, 3 in. diameter Various pcs, 1 to 2 in. diameter
Aggregate--25 lb ($+0, -2$)	3/8- to 3/4-in. gravel

Fragment samples of this specification are designated Mk 1 Mod 0 rubble. They differ from the samples used in the first series of track tests in that they contained an average of $1\frac{1}{2}$ lb less concrete.

---

*The frangible covers used in this test series were from a different manufacturer than those used in the first series. They were found to be too fragile and were, therefore, reinforced with tape as shown in Fig. 1.

**The full-scale cubicle tests have not provided sufficient data on fragment size and distribution to warrant a precise selection of fragments for the impact tests. The fragment specifications used cover the range of sizes most frequently encountered in cubicle tests, but the looseness of the specifications permits variations (within the specifications) from round to round. The existence of variations is probably in itself realistic, but the effect on acceptor detonation of the size of individual fragments in a multifragment specimen is not presently known. In the limited number of tests conducted to date, it is possible that these variations could cause seemingly anomalous results.

WATER-BRAKE SETUP

Water-braking action was provided by fastening polyethylene bags, partially filled with water, to the last 12 ft of track. Sled deceleration was effected when the wedge on the front of the sled hit the water-filled bags. Water-brake, deflector plate and target are shown in Fig. 2.

DEFLECTOR PLATE

A standard 2-inch deflector plate, placed 6 ft from the end of the track at a 5-deg angle from the track centerline, was used to deflect the test vehicle to keep it from striking the target.

TARGET

For rounds 1, 2, 3, 7, 8, 12, and 13 standard 100-lb dividing wall acceptor charges, each assembled with a full complement of detonators, were used as targets.* For rounds 4, 5, 6, 9, 10, and 11 the charges were identical to those described above except all detonators were omitted. For each round, an acceptor-charge target was placed on a wooden stand at +30 ft from the muzzle end of the track. The charge was oriented so that the flanged surfaces were normal to the length of the track.

INSTRUMENTATION

<u>Cameras</u>. One 16mm Fastax camera operating at approximately 2,500 frames/sec and one 35mm Fastax camera operating at approximately 1,500 frames/sec were located (to the side of the target) 100 ft from track centerline to record fragment impact. One Bowen CZR camera operating at 90 frames/sec was located 400 ft from track centerline to cover the area from approximately -65 to +33 ft from the muzzle end of the track. Camera locations are shown in Fig. 3.

<u>Velocity-Measuring Systems</u>. For on-the-spot sled velocity measurements, carbon rods and photo cells were installed on the track as close as possible to the beginning of the water brake. For each firing, two carbon rods were installed across the track 29.918 ft apart. A bolt projecting down from the center of the water-brake wedge on the sled broke the rods when the sled passed over them. The pulse was transmitted to the telemetering station and recorded on calibrated tape, providing a record of sled travel time between the two points.

---

*For a complete description of acceptor charge configuration and assembly, see TPR 324, Supplement, NOTS TP 3277, the Confidential Restricted Data Supplement to this report.

A second velocity-measuring system consisted of blades projecting from the side of the sled to intercept the light beams from two photo cells installed alongside the track 26.375 ft apart. The data were telemetered and recorded in the same manner as that of the carbon rod measuring system. The two systems provided a check and backup for each other.

TEST METHOD

Operation of the test vehicle consisted of the following two major phases: (1) rocket-propelled vehicle acceleration to a predicted velocity, and (2) release of the fragments through the frangible cover of the container by water-brake deceleration of the vehicle. The velocity of the vehicle was controlled by the number of rocket motors used, by changing the distance of the ignition point from the point of water-brake activation, and by varying the weight of the sled, as shown in the following table.

Sled velocity (fps)	Motor & sled configuration	Total weight (lb)	Ignition point (ft from muzzle)
875	2 live HVARs	306	-1,500
530	1 live HVAR 1 inert HVAR (empty)	301	-290
375	1 live HVAR 1 inert HVAR (weighted)	371	-220

TEST RESULTS

Thirteen rounds were fired on 16, 17, and 18 January 1963 under E-7380 with the following results:

Acceptor Reaction

All five rounds in the 750-fps fragment-velocity range produced high-order detonations, including the two fired against acceptors without detonators. In the four rounds in which fragment velocity was 330 fps, no reaction occurred in either type of acceptor. In the other four rounds, with fragment velocity at 470 fps, one of two acceptors without detonators went high order as did both of the acceptors with detonators. Acceptor reaction is tabulated below:

Round	Fragment velocity (fps)	Acceptor Type	Detonation
1, 2, 3	750	w/detonators	high order
4, 5	750	w/o detonators	high order
6	470	w/o detonators	high order
7, 8	470	w/detonators	high order
9	470	w/o detonators	none
10, 11	330	w/o detonators	none
12, 13	330	w/detonators	none

Film records from the two Fastax motion-picture cameras show that the eight acceptor charges that detonated did so in place, on their stands. The films also show that for at least 50% of these rounds, acceptor reaction started when less than one-half of the fragment sample had impacted the charge. It is impossible to determine with certainty

if this were true on the other detonating rounds because of the difficulty in fixing the time of the start of acceptor reaction. No fragments were recovered from the acceptors that detonated. Figures 4 through 11 are 35mm Fastax film frames of the detonations.

Figures 12 through 16, also taken from the 35mm Fastax records, show the impact of the fragments on the five acceptor charges that did not detonate. All of these charges were recovered in damaged condition at distances of 100 to 300 ft from their test stand. Typical damage sustained by the charges is illustrated in Figs. 17 through 20.

Equipment Performance

Sled, water brake, and deflector plate performed satisfactorily. Film records show separation of the fragment mass from the sled parts to be at least 4 ft for every round.

Fragment Cloud Characteristics. The cohesiveness of the fragment cloud appeared to be somewhat dependent upon velocity. The fragments in the higher velocity rounds remained in a well-defined mass. Those in the slower rounds appeared to spread slightly more. The cloud in round 13 was definitely elongated.

Velocity Data

Fragment and sled velocities are tabulated in the appendix. Fragment velocity data obtained from the 35mm Fastax camera are estimated to be accurate to about ±25 fps. No timing was obtained from the 16mm camera. Although spray from the water brake obscured fragment travel from the Bowen camera, sled velocities were obtained. They were also recorded by the carbon-rod and photo-cell velocity-measuring systems. Sled velocities are estimated to be accurate to ±15 fps.

Comparison With Previous Test Results

Using velocity and detonation data obtained from cubicle tests combined with the data obtained from the two series of track tests, the following comparisons are made:

Cubicle Tests			Detonations	Track Tests	
Test No.	Wall (in)	Fragment Velocity (fps)		Fragment Velocity (fps)	Test No.
B-2	12	1,150	X		
			X X	850	E-7101
C-10	18	800	X		
			X X X X* X*	750	E-7380
C-10	24	700	X		
			X P O	550	E-7101
C-6	12	500	O		
			X* X X O*	470	E-7380
C-11	24	450	X		
			X O O	400	E-7101
			O* O* O O	330	E-7380
C-6	12	200	O		

* = acceptor w/o detonators
X = high-order detonation
O = no detonation
P = partial detonation

NOTE: Cubicle test velocities given to nearest 50 fps.

The table shows a higher percentage of detonations in the 470-fps velocity range than in the 550-fps range due, probably, to the small number of tests involved. However, it is possible that variations in the fragment specimen (second footnote, p. 2) could have had some effect upon results. Also, the second track test series provides some evidence that the fragment-velocity data from the first track series (estimated as accurate to only ±100 fps) could be consistently high (see appendix). This would place most of the rounds in the 470- and 550-fps ranges very near the same velocity. See velocity and detonation graph, Fig. 21.

CONCLUSIONS

In the two track test series, no detonations have occurred below a nominal 400 fps, but the spread of the individual velocity data points shows the possibility, if the minimum values are used, that detonation has occurred at a velocity as low as 300 fps. Again on the basis of the data-point spread but using maximum values, it is also possible that no detonations have occurred at velocities below approximately 500 fps. Although the data are limited, for the conditions tested the threshold detonation velocity appears to lie somewhere between 300 and 500 fps. For lack of strong evidence at either end of the 300-500 fps range, around 400 fps seems to be a reasonable area for more intensive investigation of the threshold detonation velocity.

Between approximately 750 and a nominal 850 fps, 100% detonations have occurred in seven track tests. However, lack of data between a nominal 500 and 750 fps curtails further speculation on the lower limits of the all-fire range.

Agreement between cubicle and track test data appears good. This can be taken as a limited indication that the fragment specimens used for the track tests are realistic.

Results of the second track series also indicate that, for the particular acceptor charge tested, the presence of detonators has little apparent effect upon detonation. This makes it possible to extend the interpretation of the results of cubicle tests involving these acceptors to include other light-cased or bare explosive charges.

Future Plans

In addition to the investigation of the threshold detonation velocity of Mk 1 type rubble impacting standard dividing wall acceptors, a test program to investigate the effects of various combinations of fragment mass and impact velocity on cased and uncased acceptor explosives is currently being planned.

Appendix

EVALUATION OF TRACK TEST VELOCITY DATA

Fragment velocity data obtained in track test series E-7380 were more reliable than those obtained in the earlier E-7101 track test series (see Appendix A, NAVWEPS Report 8073). The 35mm black-and-white camera coverage of fragment travel was clearer and more easily read than the 16mm color film used in the earlier series. In addition, a plainly marked backboard for camera reference (not used in the first series) was used in each round of the E-7380 series. The velocity data for this series are presented below:

Round No.	Sled velocity (fps)				Frag. velocity (fps)	
	Carbon rod	Photo cell	Bowen camera	Average (to 5 fps)	35mm Fastax	Average (to 5 fps)
1	---	878	885	875	764	750
2	867	878	875		760	
3	---	878	880		752	
4	880	---	866		750*	
5	880	878	875		730	
6	534	528	535	530	478	470
7	539	528	543		471	
8	525	---	527		452	
9	530	528	---		477	
10	365	368	---	375	330	330
11	---	371	382		329	
12	369	366	374		329	
13	381	377	384		335	

*Estimated

As noted in NAVWEPS Report 8073, the accuracy of fragment velocities in E-7101 tests was estimated at ±100 fps, while that of the second track series is estimated at ±25 fps. Sled velocities recorded by the Bowen cameras are accurate to approximately ±15 fps for both test series. If the relationship between fragment and sled velocities can be assumed to be the same for both series, then the fragment velocities recorded in the earlier series are too high compared with the more dependable fragment-velocity data obtained in the second series.

If the fragment-velocity data obtained during the first series are adjusted to coincide with the sled-to-fragment velocity relationship noted in the second series, the average fragment velocities from the E-7101 tests would be reduced by approximately 50 fps in each velocity range.

Beacuse of changes in test conditions for the second track series (i.e., the taping of the frangible plastic cover) that could have affected the sled-to-fragment velocity relationship,* the velocity data figures from E-7101 as originally presented in NAVWEPS Report 8073, are used here although they may be higher than the actual velocities attained. This should be taken into consideration when reaching conclusions based on the data presented. Figure 21 shows the spread of the velocity data points.

*The effect, if any, on fragment velocity created by the tape reinforcing on the frangible covers, cannot be assessed.

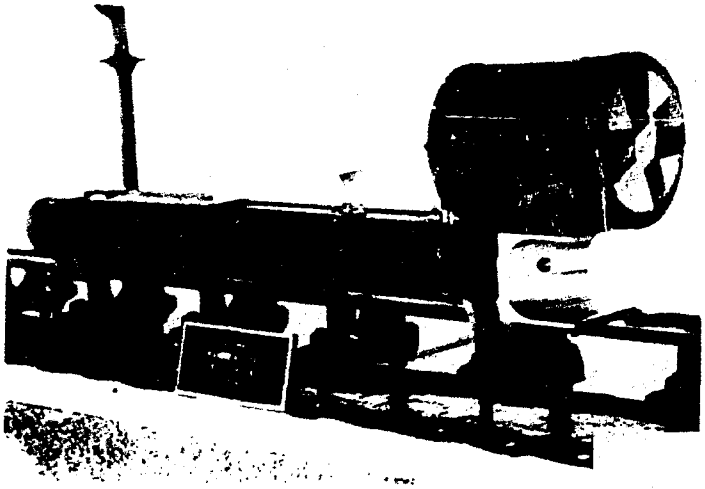
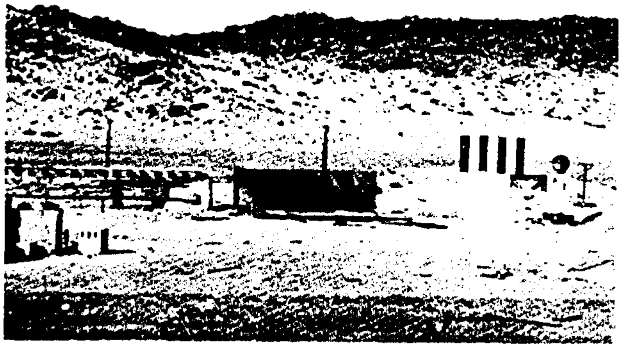


FIG. 1. Front View of Fragment Sled on Track.

FIG. 2. Detail of Test Setup Showing Water Brake, Deflector Plate and Acceptor Charge Target.



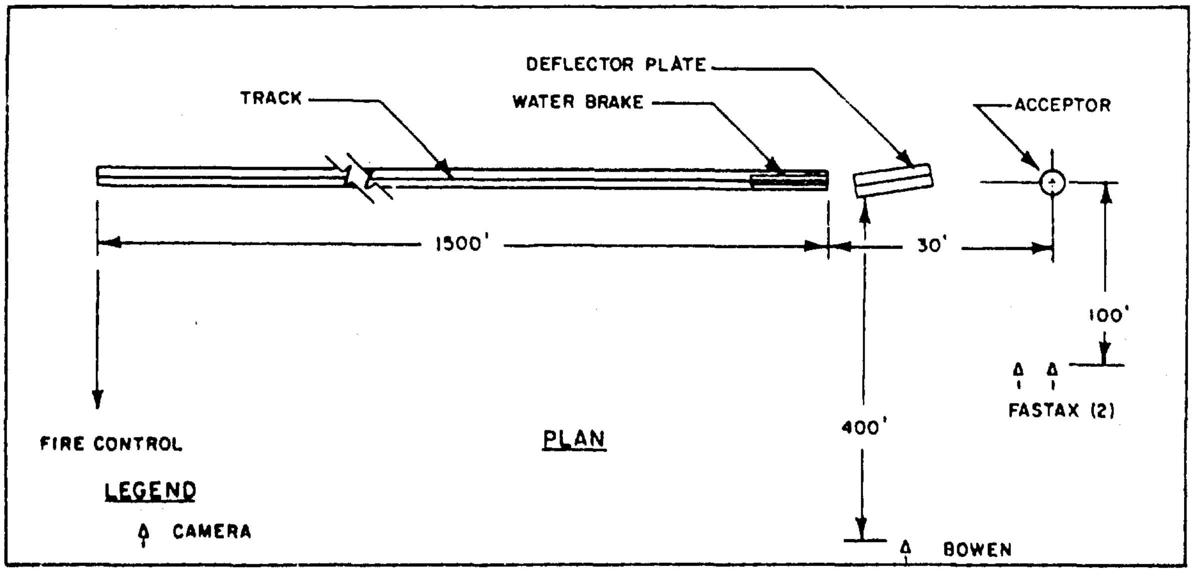


FIG. 3. Test Setup Showing Camera Locations.

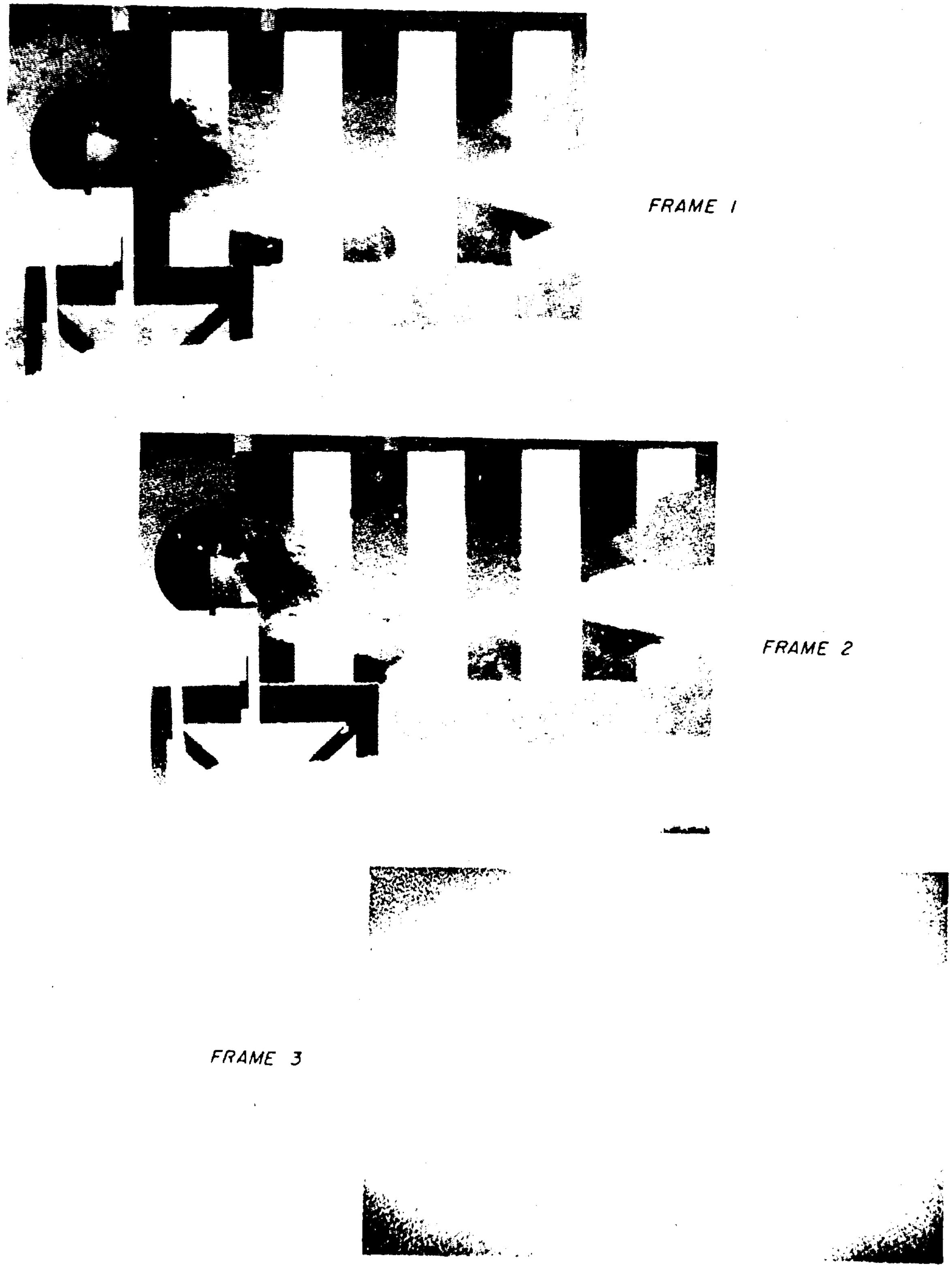
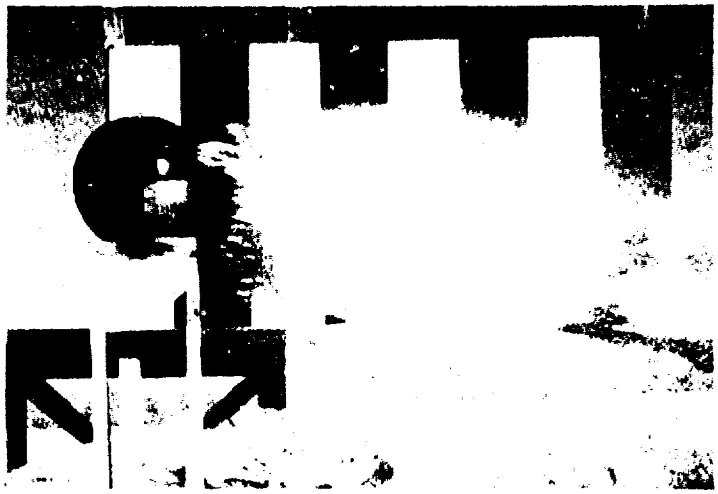


FIG. 4. Fragment Impact, Round 1. (Acceptor with detonators, fragment velocity 750 fps, frame rate 1760/sec.)

FRAME 1



FRAME 2

FRAME 3

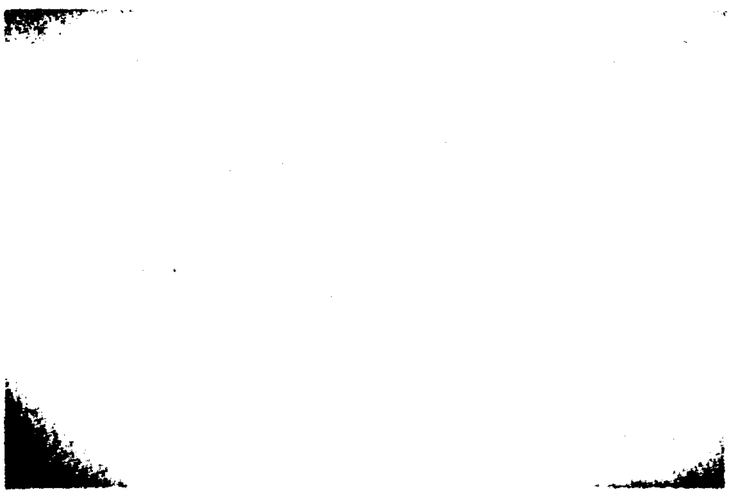


FIG. 5. Fragment Impact, Round 2. (Acceptor with detonators, fragment velocity 750 fps, frame rate 1760/sec.)

BEST AVAILABLE COPY

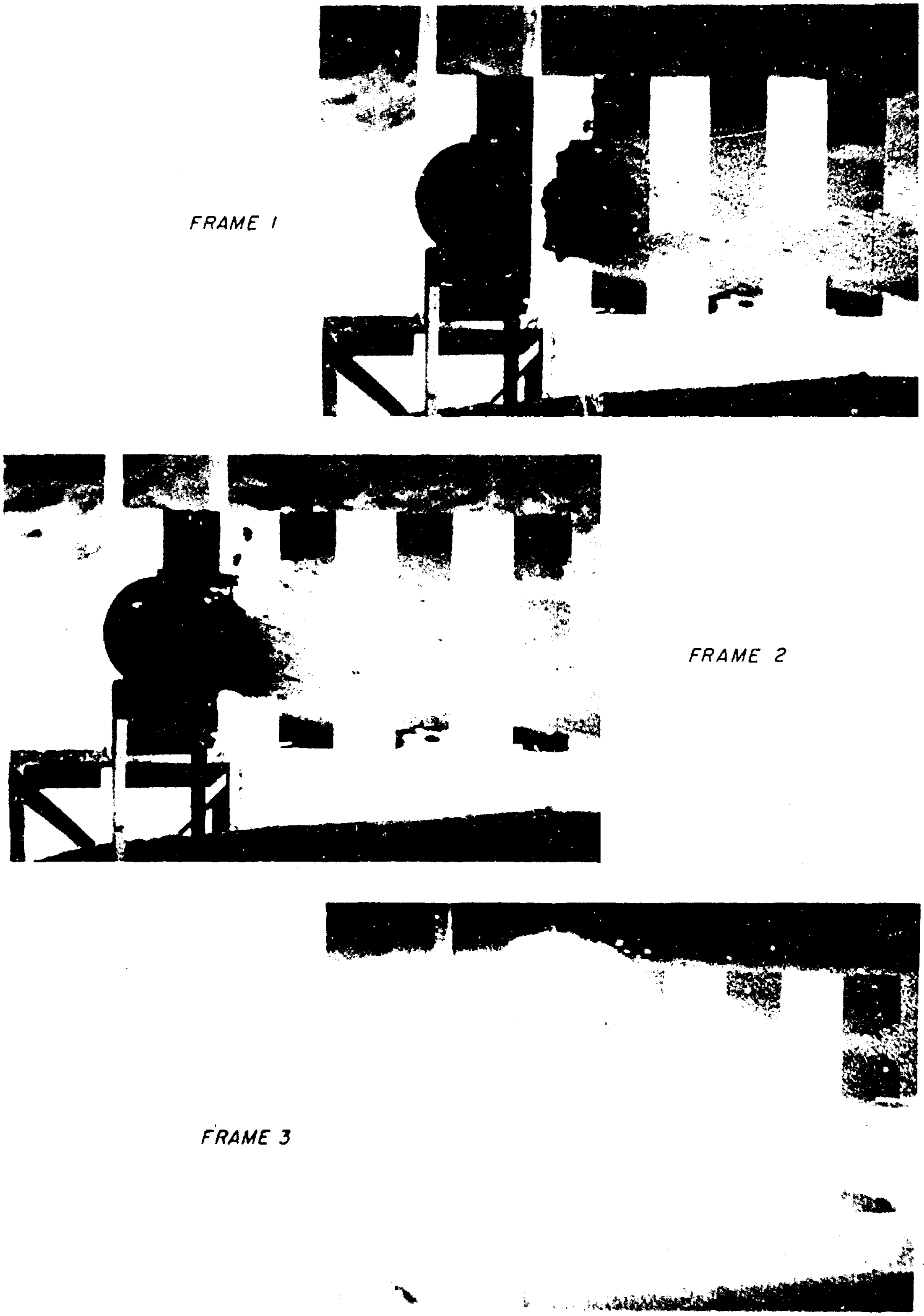
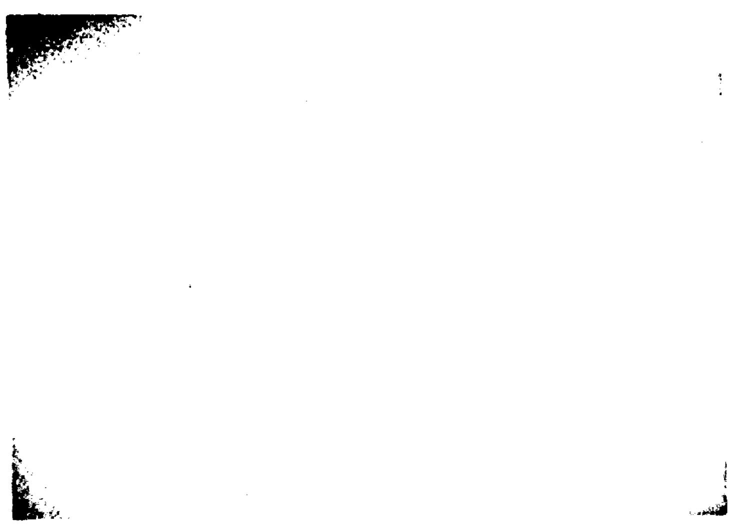


FIG. 6. Fragment Impact, Round 3. (Acceptor with detonators, fragment velocity 750 fps, frame rate 1800/sec.)

BEST AVAILABLE COPY

FRAME 1

FRAME 2



FRAME 3

FIG. 7. Fragment Impact, Round 4. (Acceptor without detonators, estimated fragment velocity 750 fps, no timing.)

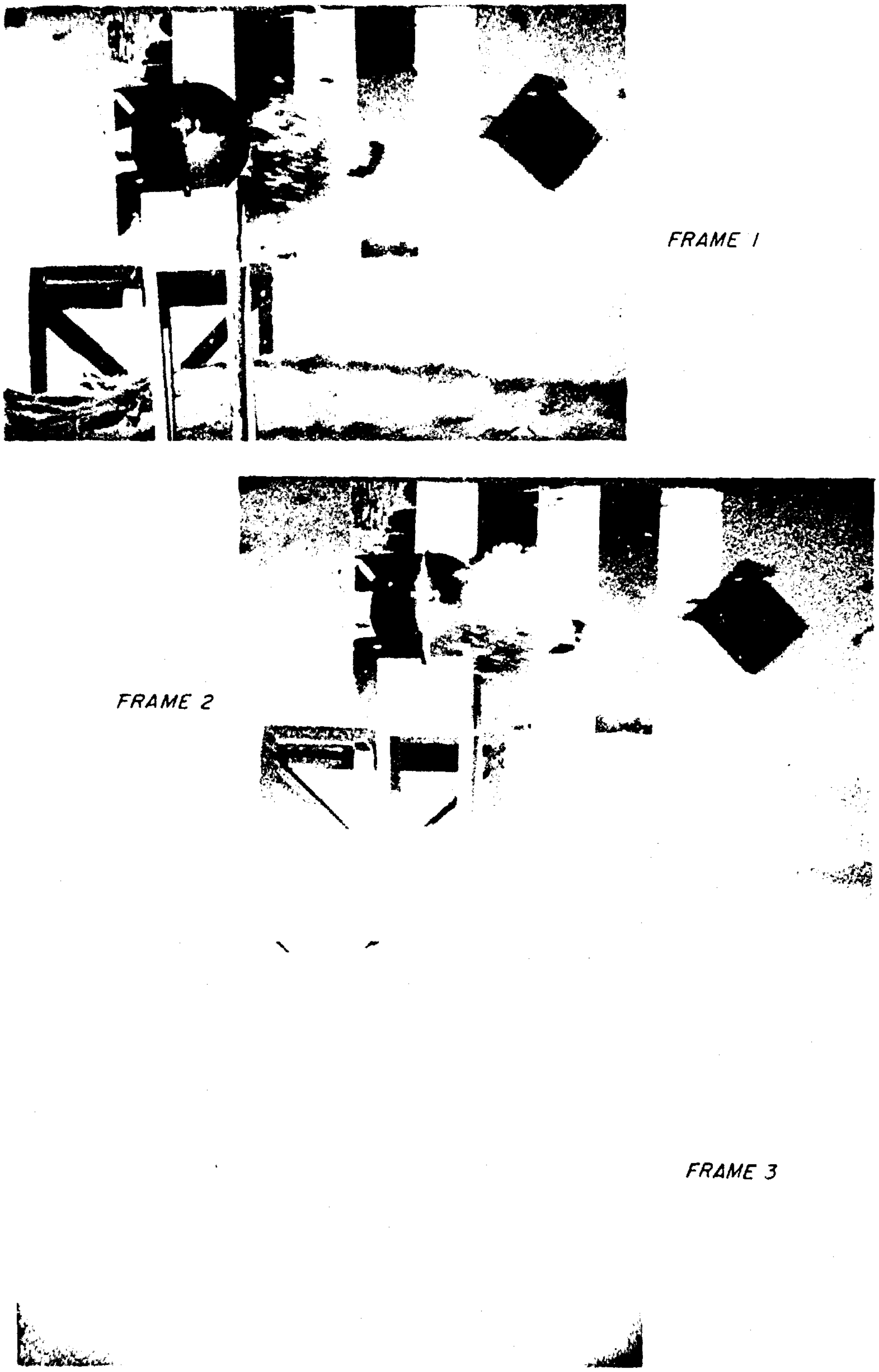


FIG. 8. Fragment Impact, Round 5. (Acceptor without detonators, fragment velocity 750 fps, frame rate 1720/sec.)

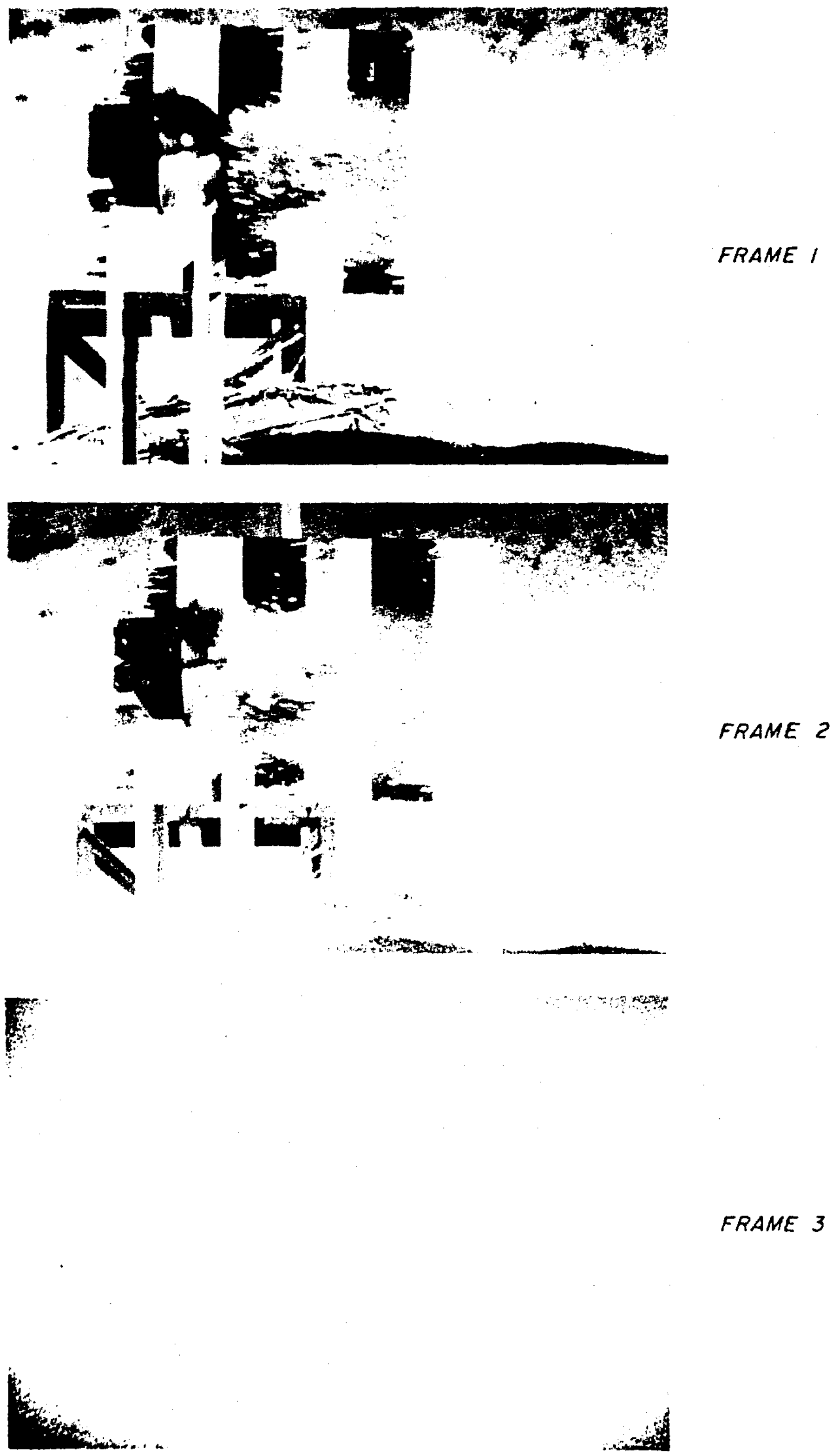


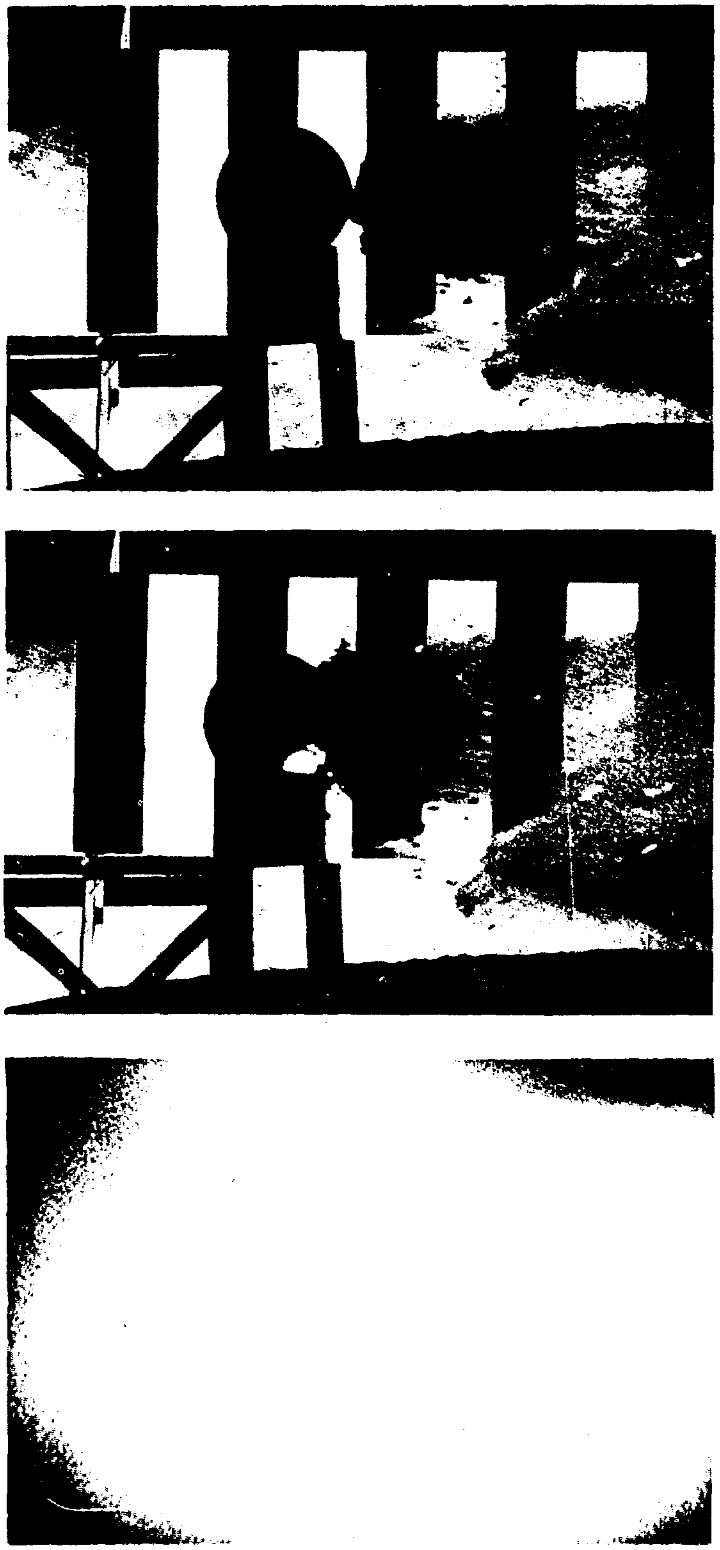
FIG. 9. Fragment Impact, Round 6. (Acceptor without detonators, fragment velocity 470 fps, frame rate 1290/sec.)

FRAME 1

FRAME 2

FIG. 10. Fragment Impact, Round 7. (Acceptor with detonators, fragment velocity 470 fps, frame rate 1110/sec.)

BEST AVAILABLE COPY



FRAME 1

FRAME 2

FRAME 3

FIG. 11. Fragment Impact, Round 8. (Acceptor with detonators, fragment velocity 470 fps, frame rate 1290/sec.)

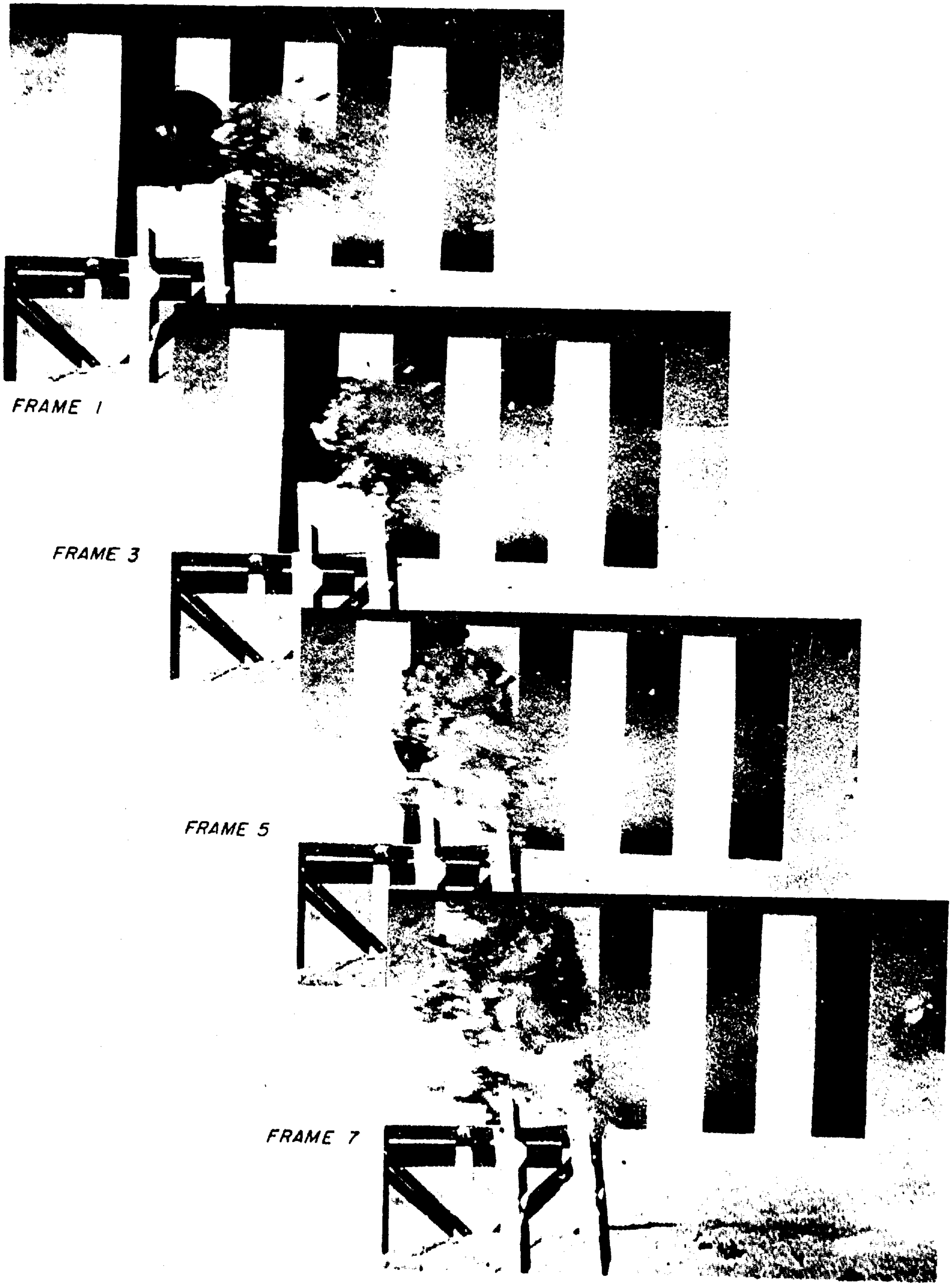


FIG. 12. Fragment Impact, Round 9. (Acceptor without detonators, fragment velocity 470 fps, no detonation, frame rate 1320/sec.)

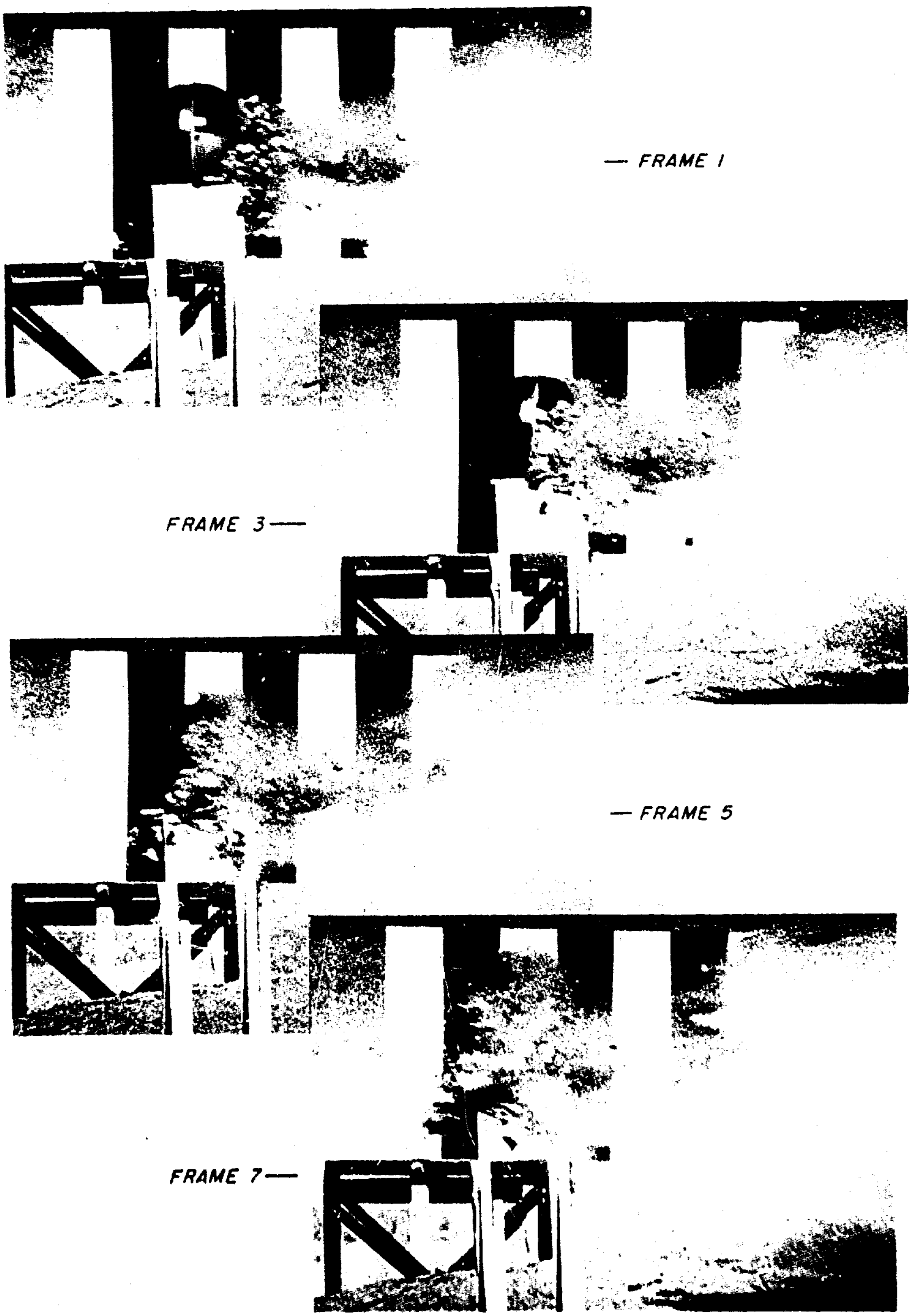


FIG. 13. Fragment Impact, Round 10. (Acceptor without detonators, fragment velocity 330 fps, no detonation, frame rate 1250/sec.)

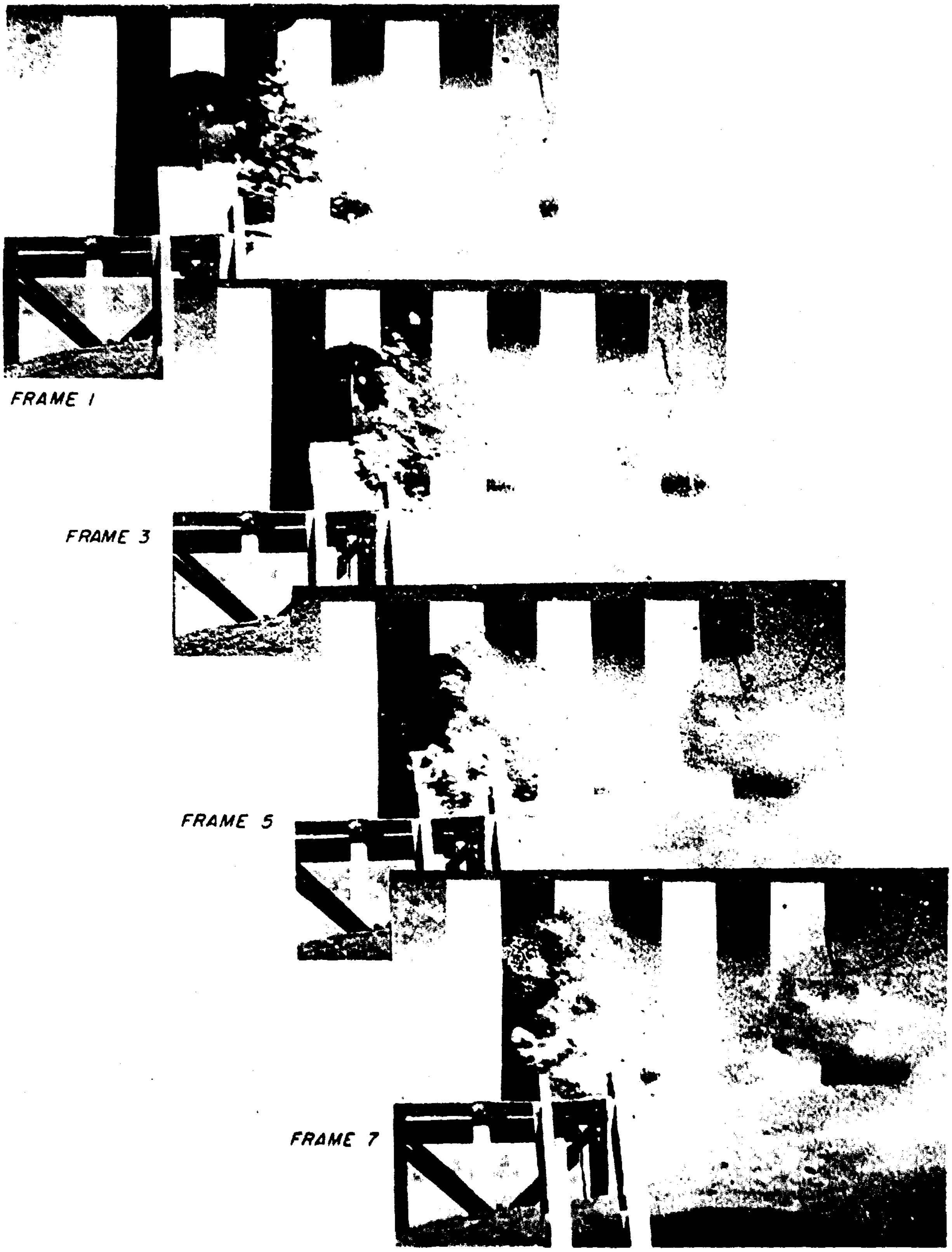


FIG. 14. Fragment Impact, Round 11. (Acceptor without detonators, fragment velocity 330 fps, no detonation, frame rate 1310/sec.)

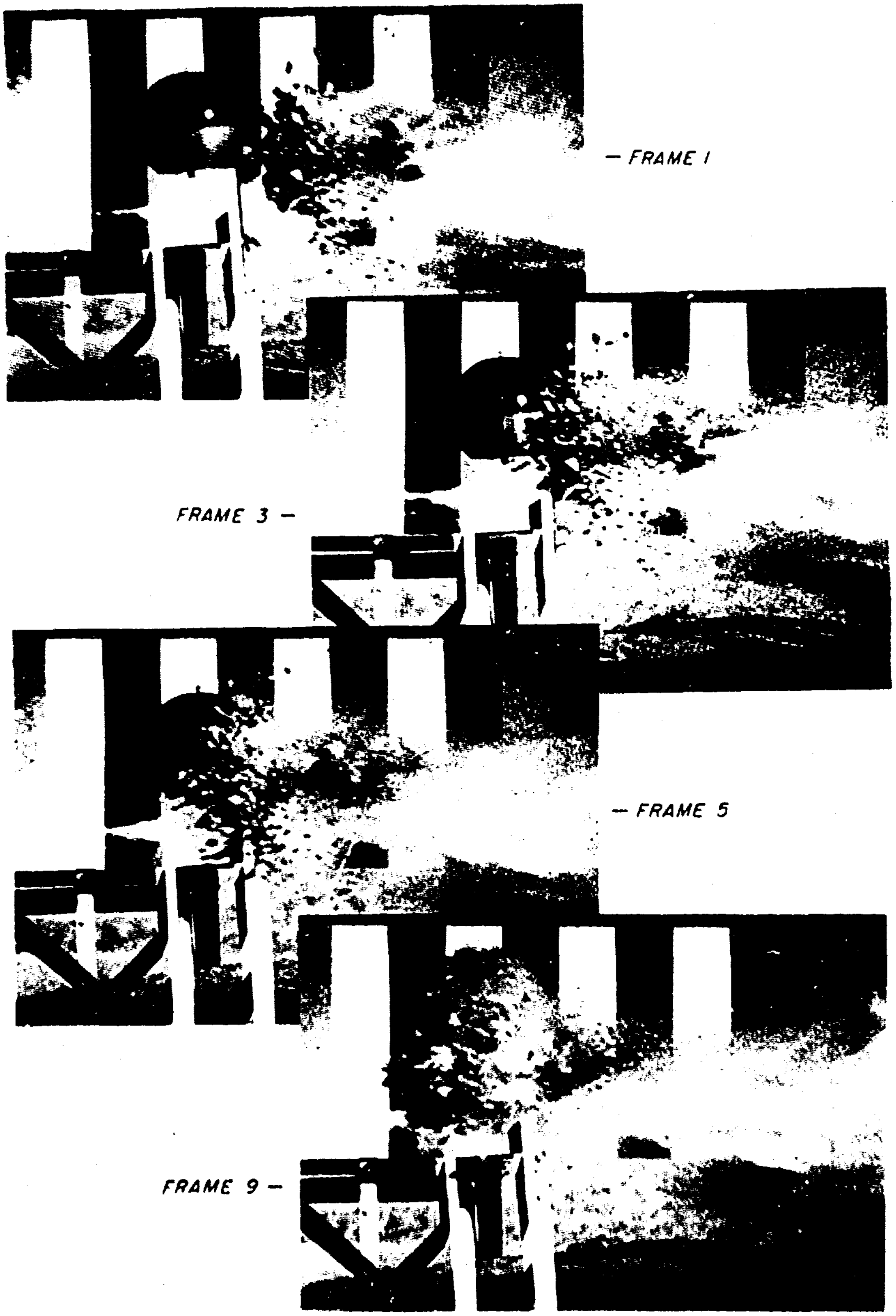


FIG. 15. Fragment Impact, Round 12. (Acceptor with detonators, fragment velocity 330 fps, no detonation, frame rate 1400/sec.)

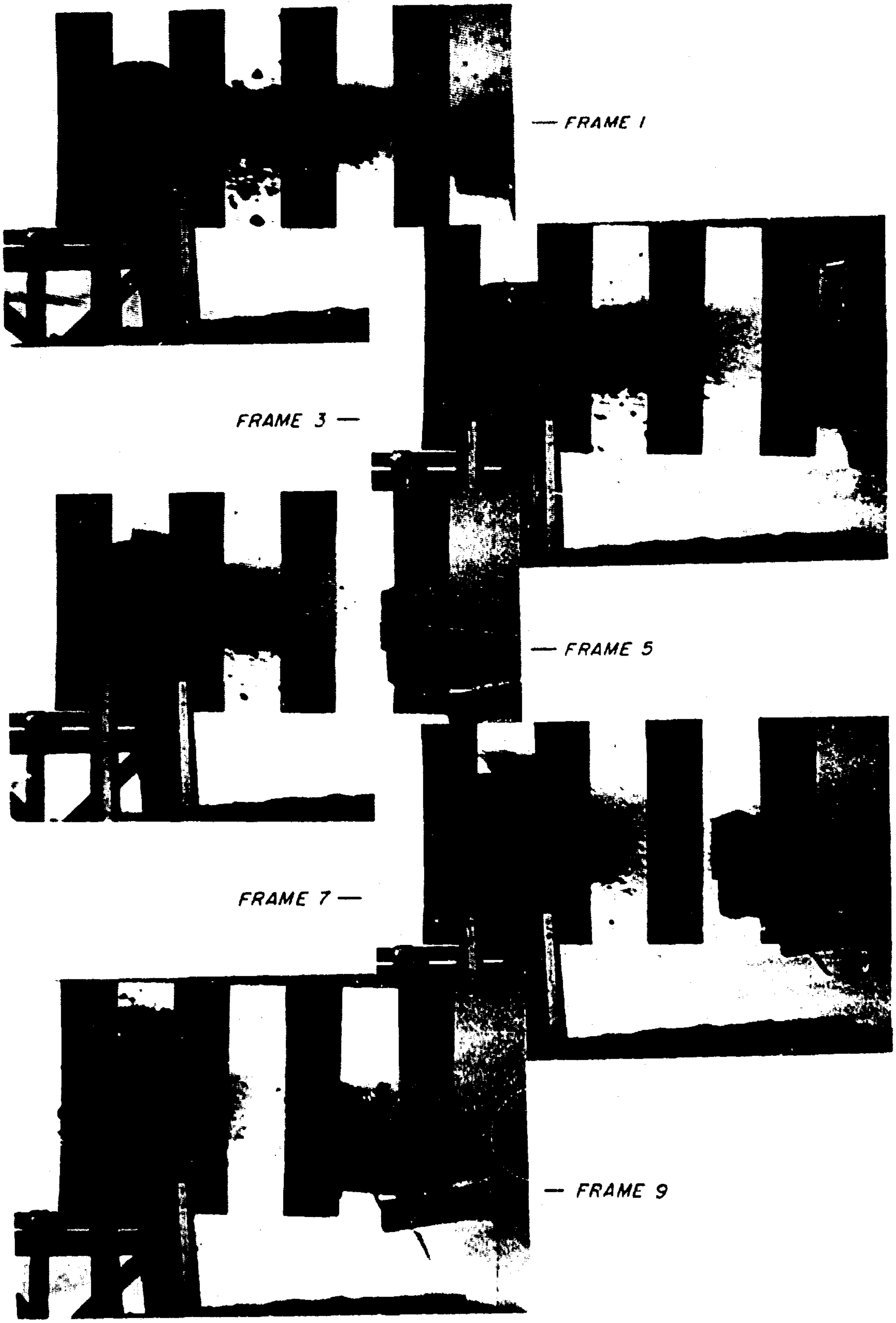


FIG. 16. Fragment Impact, Round 13. (Acceptor with detonators, fragment velocity 330 fps, no detonation, frame rate 1380/sec.)

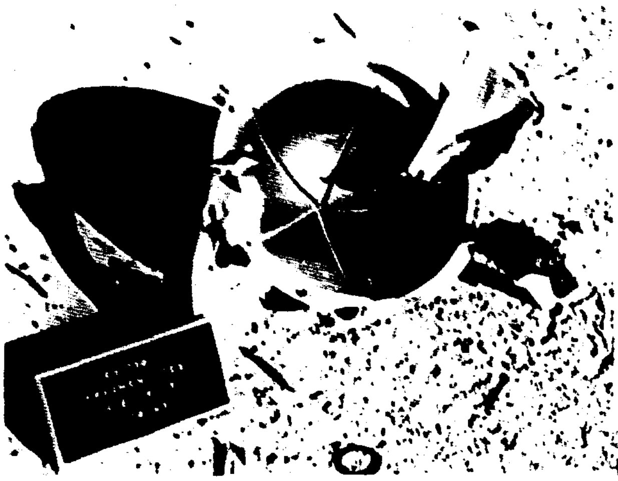


FIG. 17. Acceptor Damage, Round 9.

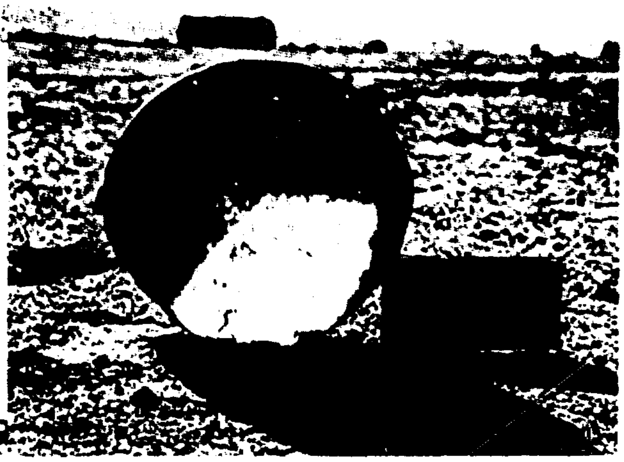


FIG. 18. Acceptor Damage, Round 10.

FIG. 19. Acceptor Damage, Round 11.

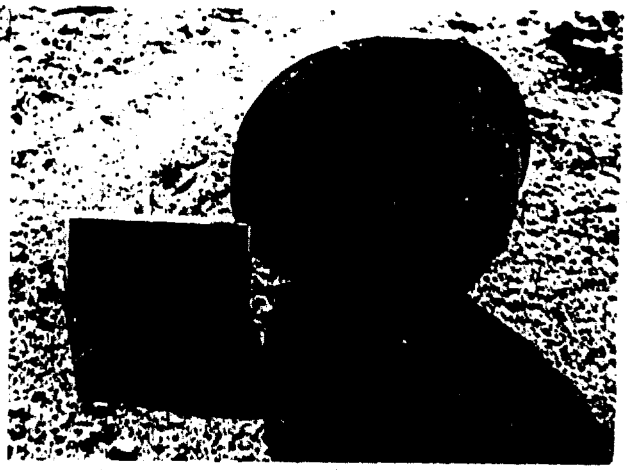


FIG. 20. Acceptor Damage, Round 12.

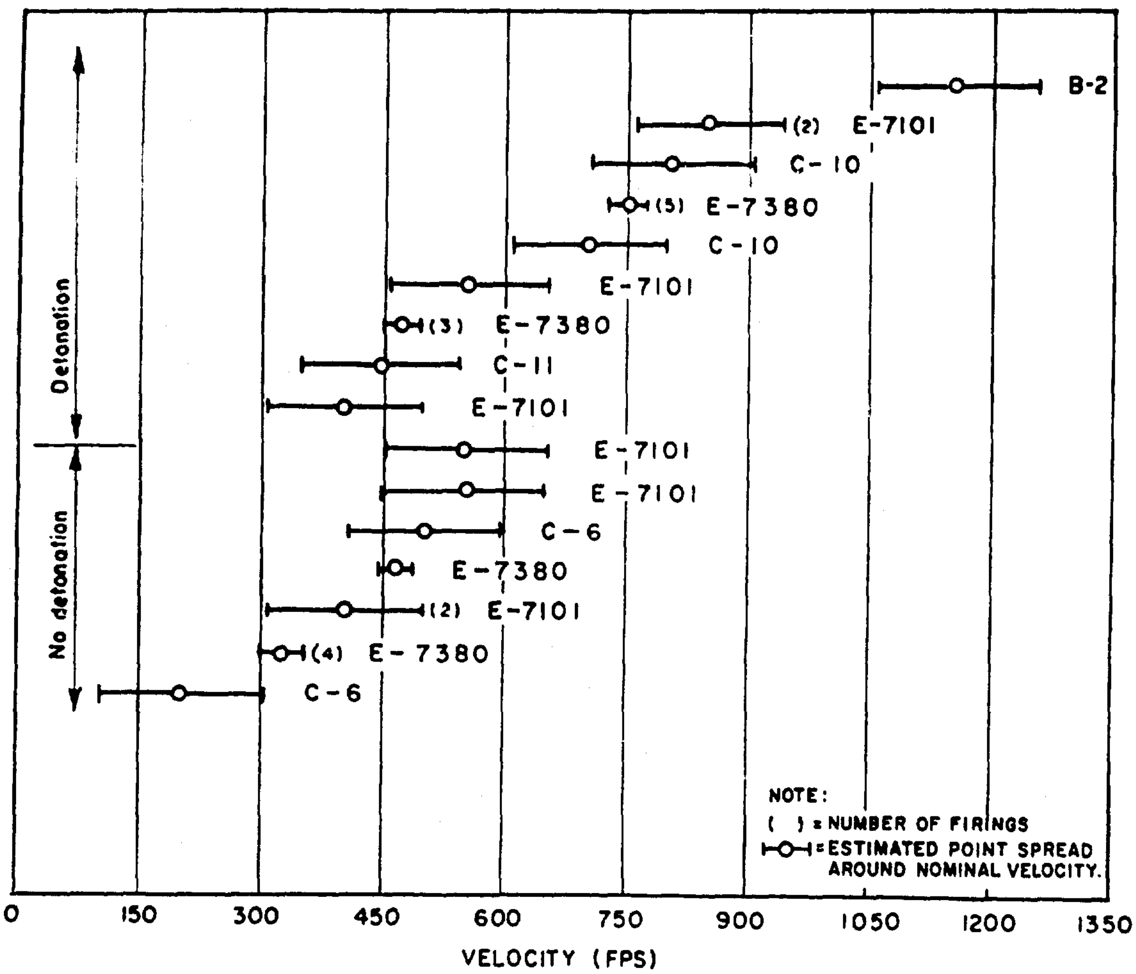


FIG. 21. Velocity and Detonation Chart.

ABSTRACT CARD

U. S. Naval Ordnance Test Station

<u>Investigation of Explosives Sensitivity to Multiple-Fragment Impact (Track Test E-7380)</u>, by L. M. Patton. China Lake, Calif., NOTS, July 1963. 26 pp. (TPR 324, NOTS TP 3276), UNCLASSIFIED.

<u>ABSTRACT</u>. In a second series of multifragment impact track tests in the ASESB dividing wall program, a rocket-powered sled was used to throw collections of fragments at explosive acceptor charges. Of the 13 rounds in this series, five, having a fragment

(Over)
1 card, 4 copies

U. S. Naval Ordnance Test Station

<u>Investigation of Explosives Sensitivity to Multiple-Fragment Impact (Track Test E-7380)</u>, by L. M. Patton. China Lake, Calif., NOTS, July 1963. 26 pp. (TPR 324, NOTS TP 3276), UNCLASSIFIED.

<u>ABSTRACT</u>. In a second series of multifragment impact track tests in the ASESB dividing wall program, a rocket-powered sled was used to throw collections of fragments at explosive acceptor charges. Of the 13 rounds in this series, five, having a fragment

(Over)
1 card, 4 copies

U. S. Naval Ordnance Test Station

<u>Investigation of Explosives Sensitivity to Multiple-Fragment Impact (Track Test E-7380)</u>, by L. M. Patton. China Lake, Calif., NOTS, July 1963. 26 pp. (TPR 324, NOTS TP 3276), UNCLASSIFIED.

<u>ABSTRACT</u>. In a second series of multifragment impact track tests in the ASESB dividing wall program, a rocket-powered sled was used to throw collections of fragments at explosive acceptor charges. Of the 13 rounds in this series, five, having a fragment

(Over)
1 card, 4 copies

U. S. Naval Ordnance Test Station

<u>Investigation of Explosives Sensitivity to Multiple-Fragment Impact (Track Test E-7380)</u>, by L. M. Patton. China Lake, Calif., NOTS, July 1963. 26 pp. (TPR 324, NOTS TP 3276), UNCLASSIFIED.

<u>ABSTRACT</u>. In a second series of multifragment impact track tests in the ASESB dividing wall program, a rocket-powered sled was used to throw collections of fragments at explosive acceptor charges. Of the 13 rounds in this series, five, having a fragment

(Over)
1 card, 4 copies

TPR 324

velocity of 750 fps, produced five acceptor detonations; four rounds, at 470 fps, produced three detonations; and four rounds, at 330 fps, produced no detonations. The presence or absence of detonators in the acceptor charges had little apparent effect upon results. Specific warhead and explosives data relative to this series appear in Confidential Restricted Data report TPR 324, Supplement, NOTS TP 3277.

Results of the first series of multifragment impact track tests are reported in NAVWEPS Report 8073, NOTS TP 3090 (Unclassified), dated December 1962.

TPR 324

velocity of 750 fps, produced five acceptor detonations; four rounds, at 470 fps, produced three detonations; and four rounds, at 330 fps, produced no detonations. The presence or absence of detonators in the acceptor charges had little apparent effect upon results. Specific warhead and explosives data relative to this series appear in Confidential Restricted Data report TPR 324, Supplement, NOTS TP 3277.

Results of the first series of multifragment impact track tests are reported in NAVWEPS Report 8073, NOTS TP 3090 (Unclassified), dated December 1962.

TPR 324

velocity of 750 fps, produced five acceptor detonations; four rounds, at 470 fps, produced three detonations; and four rounds, at 330 fps, produced no detonations. The presence or absence of detonators in the acceptor charges had little apparent effect upon results. Specific warhead and explosives data relative to this series appear in Confidential Restricted Data report TPR 324, Supplement, NOTS TP 3277.

Results of the first series of multifragment impact track tests are reported in NAVWEPS Report 8073, NOTS TP 3090 (Unclassified), dated December 1962.

TPR 324

velocity of 750 fps, produced five acceptor detonations; four rounds, at 470 fps, produced three detonations; and four rounds, at 330 fps, produced no detonations. The presence or absence of detonators in the acceptor charges had little apparent effect upon results. Specific warhead and explosives data relative to this series appear in Confidential Restricted Data report TPR 324, Supplement, NOTS TP 3277.

Results of the first series of multifragment impact track tests are reported in NAVWEPS Report 8073, NOTS TP 3090 (Unclassified), dated December 1962.

INITIAL DISTRIBUTION

3 Chief, Bureau of Naval Weapons
    DLI-31 (2)
    RUME-32, E. M. Fisher (1)
1 Chief, Bureau of Yards and Docks (Otis Hudson)
1 Chief of Ordnance (AMCAD-SA, W. G. Queen)
1 Chief of Engineers (G. F. Wigger)
1 Army Ammunition Procurement and Supply, Joliet
1 Picatinny Arsenal (SMUPA-DE2, L. W. Saffian)
3 Headquarters, U. S. Air Force
    AFIIS, W. G. Weller (1)
    AFMSS, Col. Robert B. Baker (1)
    AFOCE-K, J. R. Powers (1)
1 Ogden Air Materiel Area, Hill Air Force Base (N. W. Harbertson)
1 Norton Air Force Base (AFIAS-G2, D. E. Endsley)
4 Armed Services Explosives Safety Board (R. G. Perkins)
1 Defense Atomic Support Agency (Logistics Division, E. L. Taton)
10 Defense Documentation Center
2 National Aeronautics and Space Administration
    Code BY, Erskine Horton (1)
    Code MLO (1)
1 Albuquerque Operations Office, AEC, Albuquerque (E. L. Brawley)
1 Mason and Hanger - Silas Mason Company, Inc., Pantex Ordnance Plant (I. B. Akst)